National Quail Symposium Proceedings

Volume 2 Article 3

1982

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ESTIMATING BOBWHITE POPULATION SIZE BY DIRECT COUNTS AND THE LINCOLN INDEX

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Abstract: Thirteen paired estimates of bobwhite (*Colinus virginianus*) populations were obtained using the Lincoln Index and a Walk Census on two study areas in Florida and one in Tennessee. Population densities ranged from 1.0 to 7.6 birds/ha as estimated by the Lincoln Index. Unadjusted estimates obtained by the Walk Census averaged 51 percent of those obtained by the Lincoln Index. The correlation coefficient (r) for the 13 paired estimates was 0.96. The linear relationship between the Walk Census and Lincoln Index estimates was defined by $\hat{y} = 1.65x + 101.6$, where $\hat{y}$ = Lincoln Index estimate and x = Walk Census estimate. The Lincoln Index gave an unbiased estimate of the "true" population; either adjusting the Walk Census estimates by doubling the count or using the predictive equation generally produced acceptable estimates of the "true" population.

Assessing the effects of habitat manipulation and/or harvest regulations often requires measuring the animal population of interest. Capture-recapture methods and direct counts are two commonly used techniques for estimating the number of animals on defined areas (Davis and Winstead 1980). Both of these approaches have been used to evaluate bobwhite populations over a variety of habitat types. Managers and researchers continue to use variations of both these methods, though neither their accuracy nor precision have been clearly defined.

Capture-recapture estimates have used the Lincoln Index estimator in which bobwhites are captured in grain-baited live traps, banded, and released. A second sample is obtained either by shooting or trapping (Loveless 1958, Kellogg et al. 1972). Direct counts of bobwhites have usually been accomplished by workers systematically or randomly traversing an area and counting the coveys or individual birds flushed (Dimmick and Yoho 1972). Frequently, pointing bird dogs have been used to aid in locating the birds (Steen 1950, Robinson 1957, Loveless 1958, Roseberry and Klimstra 1972). Each method has its own set of advantages and disadvantages. Direct counts of flushed birds can be made comparatively quickly and require little equipment or expertise beyond simple map-reading and orientation skills. However, neither the proportion of the population counted nor the variability of this statistic over a range of habitat types and population densities has been defined. Population estimates based upon capture-recapture methods must necessarily comply with the standard assumptions regarding equal probability of capture, minimum recruitment-mortality, and retention of marks. In addition to these constraints, the technique often requires large investments of time and equipment to sample an area adequately. This approach, however, provides data which can be used to generate confidence intervals around the population estimate as well as a wealth of other population characteristics.

The primary objective of our study was to delineate relationships between the population estimate provided by the Lincoln Index and the direct count of flushed birds, which we term the Walk Census.

STUDY AREAS

Three areas were used for this study, a 234 ha tract on Ames Plantation, Fayette County, in southwest Tennessee and two tracts (204 and 212 ha) on Tall Timber Research Station, Leon County, in northwest Florida. The three areas were roughly similar in shape and size but encompassed two distinctly different habitat types.

Ames Plantation

The Ames Plantation study area was composed of cropland, idle lands, and forested areas. Forests were predominantly hardwoods in small tracts though some small stands of loblolly and shortleaf pines (Pinus taeda and P. echinata) were present also. Idle lands contained mature hardwoods scattered throughout extensive areas of broomsedge (Andropogon virginicus), creating the appearance of savanna. Forests contained moderately dense to dense growth of Japanese honeysuckle (Lonicera japonica) scattered abundantly throughout the understory. Croplands were composed of soybeans and cotton; these crops were usually harvested prior to the initiation of census work. Idle lands were burned in a checkerboard pattern on a two-year rotation, with about 50 percent being burned each year. Burning was accomplished after field studies were concluded for the year. Topography was flat to rolling; a major erosion ditch traversed the long mid-axis of the study area. Surface visibility ranged from very open to heavily obstructed by vegetation. An abundant winter food supply based on agriculture residues, dense protective cover, and high degree of interspersion of land uses provided excellent habitat quality for quail during the study period.

Tall Timbers Research Station

The Tall Timbers areas were composed principally of open, annually-burned, mature stands of loblolly and shortleaf pines with interspersed live oaks (Quercus virginiana). Understory was open, herbaceous plants dominating except for scattered experimental fire ecology plots, some of which were dense thickets of hardwoods and pine. Some low wet hammocks were occupied by live oak, beech (Fagus grandifolia, magnolia (Magnolia grandiflora), and other hardwoods. Several small fields of irregular shape were scattered throughout the areas; in some years they were planted to corn; in other years they were left fallow. Excellent visibility at surface level prevailed over almost all of both study areas. Topography was rolling. An abundance of natural foods enhanced by an annual prescribed fire program, some agricultural crop residues, and a generally mild winter climate provided an excellent environment for quail. A detailed description of the TTRS area was provided by Smith (1980).

METHODS

Lincoln Index

Quail were captured in live traps, banded with numbered aluminum leg bands, and released at the point of capture. Traps were placed at an average density of about one trap per two ha, but spacing was irregular as traps were set only in appropriate cover. Traps were baited with whole kernel or cracked corn. Trapping was continued until a very low percentage of captured birds was unbanded. Approximately 15 to 20 calendar days were required to capture sufficient numbers of quail for the estimate. Approximately two to three days following the end of trapping, systematic intensive shooting was inaugurated to collect a second sample of birds for computing the Lincoln Index. Shooting was continued until approximately one-half as many quail were shot on the area as had been banded in that year. The standard Lincoln Index then was applied to these data to obtain an estimate of the population.

The second sample (shooting) was obtained as quickly as possible following the end of trapping to reduce potential bias that could accrue from differential mortality and egress or ingress of banded vs unbanded birds. Some hunting and live-trapping were done on lands adjacent to the study areas to obtain an estimate of bias associated with egress of birds from the study area. Few marked birds were shot or trapped off the study areas, leading us to conclude that egress was not significant during the census period. Detailed information on movement of birds at Tall Timbers is given by Smith (1980).

On Ames Plantation, trapping and shooting were accomplished during November and December. On Tall Timbers this work was done during January and February.

Walk Census

Walk Censuses were conducted by teams of 5-10 persons traversing the entire study area by walking. Individuals maintained distances of approximately 20 m from persons on each side. One person served as leader and maintained direction using a handheld compass. The team worked as a unit, walking abreast at a moderate pace and maintaining appropriate spacing by visual and voice contact.

When quail were flushed, their number was counted and their location and direction of flight were noted on a detailed cover map. Questions concerning possible duplication of observed coveys, or disparate counts of the number of birds in a covey were answered immediately in the field at the point of action by consultation with team members and/or previously recorded data. When a covey was flushed but could not be counted, it was assigned a mean value determined at the conclusion of the count.

Walk Censuses were made during December on Ames Plantation and during February on Tall Timbers. A team of six persons required about 10-12 hours to complete the count on the Ames Plantation study area, and a team of 10 persons required about 8-10 hours for each of the Tall Timbers areas. Counts were made immediately following the end of a Lincoln Index trapping session and immediately prior to the initiation of shooting.

RESULTS

On the three study areas, 13 pairs of population estimates were achieved. In each case, the Lincoln Index estimate of population size was greater than its companion estimate made by the Walk Census (Table 1).

Lincoln Index Estimates

Lincoln Index estimates of population densities encountered on the study areas ranged from a low of 1.0 birds/ha on Tall Timbers South to 7.6

Table 1. Population estimation derived by Walk Censuses and the Lincoln Index on three study areas in Florida and Tennessee, 1972-1980.

		Walk Census		Lincoln Index			
Area	Year	No. Birds	Percent Flushed[a]	No. Birds	Standard Error	95% C.I.	Proportion of Population Marked[b]
Tall Timbers North							
	1972	867	56	1536	83	1370-1702	52
	1973	414	59	705	38	629-781	66
	1974	337	60	565	47	471-659	49
	1975	265	65	409	33	343-475	64
	1976	237	51	463	41	381-545	58
	1977	183	48	383	42	299-467	51
	1978	226	45	497	43	411-583	56
	1980	160	28	575	37	401-649	69
	$\overline{X}$		51.5				
Tall Timbers South							
	1978	138	64	216	31	154-278	50
	1979	239	48	496	44	408-584	55
	1980	214	40	535	60	415-655	48
	$\overline{X}$		50.7				
Ames Plantation							
	1972	548	52	1047	137	773-1321	27
	1973	395	47	848	90	668-1008	38
	$\overline{X}$		49.5				
Overall	$\overline{X}$		51.0				

[a]Percentage flushed calculated as proportion of Lincoln Index estimate of population counted during the Walk Census.
[b]Percentage of estimated population marked in capture phase of study.

birds/ha on Tall Timbers North, approximately embracing the range of densities that could be expected on moderate to excellent quail range in the Southeast (Table 2). However, the exceptionally high density of 7.6 birds/ha (3 birds/acre) observed one year on Tall Timbers North likely does not occur often nor for long periods of time on even the best southeastern quail range.

Table 2. Ranges in density of quail on each study area estimated by Walk Census and Lincoln Index.

	Birds/ha	
Area	Walk Census	Lincoln Index
Tall Timbers North	0.8 - 4.3	1.9 - 7.6
Tall Timbers South	0.7 - 1.1	1.0 - 2.6
Ames Plantation	1.7 - 2.3	3.6 - 4.5

The proportion of birds marked during the capture phase of the estimate was quite high; on the Tall Timbers study areas it ranged from 48 to 69 percent (Table 1). Smaller proportions were marked on Ames Plantation, but even on this area the estimates of population size were judged acceptable.

Walk Census Estimates

The Walk Census produced consistently lower counts of quail than were known to be present on all study areas every year (Tables 1 and 2). Based upon this method of population assessment, densities ranged from 0.7 birds/ha on Tall Timbers South to 4.3 birds/ha (1.7 birds/acre) on Tall Timbers North.

Relationships between Lincoln Index and Walk Census Population Estimates

Assuming the Lincoln Index is an unbiased estimator for population numbers of bobwhites, we decided that it would be instructive from a management viewpoint to delineate the relationships between this labor-intensive method and the relatively simple Walk Census. Two approaches to evaluating this relationship appeared feasible, one using the percentage of birds estimated by the Lincoln Index flushed on its paired Walk Census, and another using more sophisticated correlation and regression analyses of the relationship between these two sets of data.

The proportion of birds flushed by the Walk Census averaged 51 percent for the 13 paired observations, ranging from 28 to 65 percent (Table 1). Eleven of the values, however, ranged from 45 to 65 percent; the two values outside this range occurred during the same year on the two Tall Timbers study areas, suggesting that circumstances prevailing during that census period may have been substantially different than in the other 11 censuses, but we can offer no explanation for what this difference may have been. Weather and personnel were similar to other years. Mean percentages of birds flushed were nearly identical for all three study areas, i.e., 49.5 percent for Ames Plantation, 50.7 percent for Tall Timbers South, and 51.5 percent for Tall Timbers North (Table 1). Thus, within the scope of habitat variability in our study, the proportion of birds flushed was not a function of habitat type. An examination of the relationship between population density (LI) and proportion of birds flushed also revealed no trend or statistical relationship ($r = 0.0$) between these statistics.

Assuming that 51 percent of the population is flushed and counted during a Walk Census, one can roughly estimate the "true" population by doubling the number counted. When we expanded our Walk Census estimate by this method, the adjusted population fell within the 95 percent confidence interval of the Lincoln Index estimate 8 of 13 times. Four estimates were slightly above the upper limit and one was markedly below the lower limit. Only three of the expanded estimates, however, deviated more than 25 percent above or below the LI estimate.

Regression and correlation analyses were very useful for estimating the degree of bias between the two estimators. The correlation coefficient for our 13 pairs of census figures was very high ($r = 0.96$). The predictive equation for these data was $\hat{y} = mx + b$, where

$\hat{y}$ = number of quail estimated by LI,
x = number of quail counted by WC,
$m = 1.65$, and
$b = 101.6$.

Since the estimated slope (m) of 1.65 is significantly different from one, the Walk Census is a biased estimate of the population.

The graphic representation of this equation is depicted by Figure 1. The relationship is clearly linear, and holds reasonably well through the range of densities measured in this study. Expanding the Walk Census count with this predictive equation produced very good estimates for dense and very dense populations, but markedly overestimated (52 percent) a very low population. Nine of 13 expanded estimates were within the C.I.

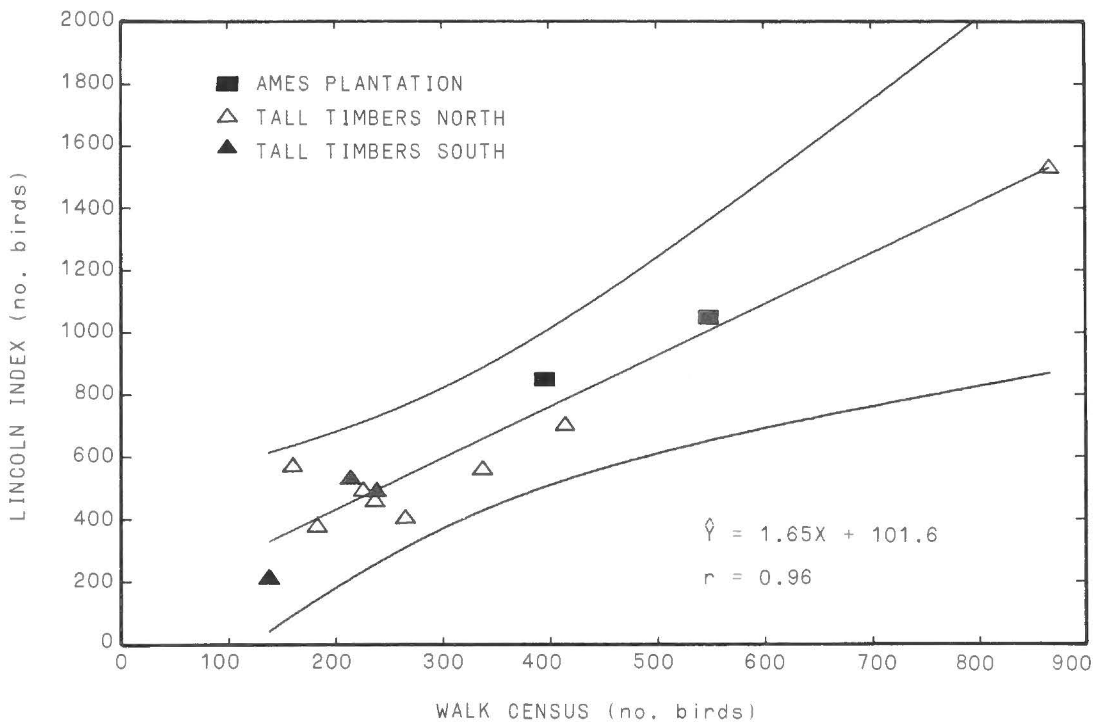

Fig. 1. Relationships between Walk Census estimate and Lincoln Index estimate on Tall Timbers and Ames Plantation study areas.

of the Lincoln Index estimate; three estimates deviated more than 25 percent from the LI estimate.

DISCUSSION AND CONCLUSIONS

We conclude that our methods for applying the Lincoln Index provided a close estimate of the bobwhite population on our study areas. Most germane to this conclusion is the stringency with which our study methods and the populations' behavior met the assumptions necessary for the Lincoln Index estimate to be accurate.

Our model was essentially a two-sample, short-term study of a closed population (see Pollock 1981). Our assumption that the populations were closed was greatly strengthened by Smith's (1980) detailed analysis of 10 years' banding data for the quail population on Tall Timbers Research Station. She described this population as extremely sedentary with movement so limited that it is not a major factor in population dynamics. She noted that trapping and shooting outside the boundaries of our study areas indicated little ingress or egress. The assumption of a closed population is further strengthened by the brief duration of the time over which the census was extended. Nichols et al. (1981) noted that selecting an appropriate time of year for sampling and allowing only a short period of time between samples will minimize violations of closure. On both Tall Timbers Research Station and Ames Plantation, the census was made when movement and mortality were low and natality was non-existent.

The assumption of equal catchability is not so clearly indicated, yet no strong biases were apparent in either the first or second sample on the basis of sex and age ratios. Pollock (1981) noted, however, that meeting the assumption of closure permits weakening the assumption of equal catchability. The problem of trap response bias for the second sample was negated by collecting that sample by shooting in a systematic fashion rather than live-trapping.

Band loss should be negligible for aluminum leg bands over a period of one to six weeks, and band reporting rate was 100 percent, since all hunting was conducted or monitored by researchers. The marked sample size was very high, averaging nearly 50 percent of the population, the lowest being 27 percent.

We agree with the evaluation of Nichols et al. (1981) that mark recapture studies can be useful in assessing other estimation methods and that in some situations mark recapture studies may be the most practical method for estimating population size. We conclude that our two-sample Lincoln Index provides the best estimate available for a closed population of bobwhites. By properly selecting boundaries for a study area, population size can readily be converted to population density.

This method of population estimation carries with it several advantages accrued from the handling of a large number of live and dead birds, specifically the opportunity to obtain sex and age ratios, movement data, population dynamics, health and condition data, etc. On the negative side of the ledger, the heavy cost in manpower, equipment, and money reduces the usefulness of this technique as a means for evaluating population trends in most management situations. Roughly 80-100 man-days were expended obtaining one estimate on one 200 ha area. Secondly, significant though not excessive mortality is imposed upon the population through trap-related deaths and shooting the second sample. The study method imposed roughly 25-30 percent mortality on the population.

The Walk Census appeared to be a reasonably precise, though biased, estimator of population numbers. It was simple and quick to execute. It correlated reasonably well with the Lincoln Index estimate over a range of conditions and a period of several years; thus we are confident that it can be highly useful as an indicator of population trends. For our study areas, it was a good indicator of population size when expanded by appropriate computations. We would be uncomfortable expanding estimates for Walk Censuses conducted in habitats greatly dissimilar from ours, e.g. very open habitats of prairie regions, but suggest that such adjustments may be acceptable for much of the midwest, midsouth, and deep south quail range.

Perhaps the greatest advantage of the Walk Census is the ease and speed with which it can be accomplished. A single estimate for a 200 ha area can be obtained with an expenditure of 8-10 man days, roughly 10 percent of the time required for the Lincoln Index. Using the appropriate number of researchers, this can be accomplished in one to two calendar days, in contrast to the 30+ calendar days required for trapping and shooting for the Lincoln Index. The Walk Census has an added advantage of imposing no mortality on the population. When researchers conduct a Walk Census, they should adhere to the following precautions:

1. Select sampling areas that are reasonably regular in shape, with boundaries as close to perpendicular as possible.

2. Use line-of-sight compasses to control direction of traverse, and adhere carefully to compass direction, walking through all cover types and densities with equal care and consistency of attention.

3. Avoid using hunting dogs. It adds another variable.

4. Carefully maintain spacing of approximately 20 m between workers. Using fluorescent orange vests and hats greatly enhances this aspect, particularly where visibility is restricted.

5. Maintain accurate records on location of coveys flushed and direction of flight. Resolve discrepancies between observers in counts immediately.

6. Walk 100 percent of the area to be censused. Our attempts at projecting data from 20 percent strip censuses failed utterly.

Following these guidelines, personnel with little training can use the Walk Census effectively, provided the team leader maintains control of personnel. The manager or biologist may enlist the aid of interested non-professionals to determine and demonstrate the relationship between habitat conditions on a given area and the density of its bobwhite population, reducing costs further with little or no sacrifice in quality of the estimate.

ACKNOWLEDGEMENTS

We thank the staff of Ames Plantation, particularily Mr. J. Bryan, Superintendent, for providing facilities for this study. J. Dabney, W. G. Minser, and R. Saunders aided in capturing quail, and R. Constalie and B. Constalie helped significantly in collecting quail for the Lincoln Index estimate. McIntire-Stennis funds administered by the University of Tennessee Agricultural Experiment Station supported the Tennessee part of this study.

The portion of these studies completed at Tall Timbers Research Station would have been impossible without the enthusiastic cooperation of the full staff, and to each one we express our sincere appreciation. This study was supported by Tall Timbers Research Station, Tallahassee, Florida, and by an appropriation from the Congress of the United States to the Southeastern Cooperative Wildlife Disease Study, The University of Georgia. Funds were administered and research coordinated under the Federal Aid in Wildlife Restoration Act (50 Stat. 917) and through Contract Numbers 14-16-0009-78-024, 14-16-0008-676, and 14-16-0008-2029, Fish and Wildlife Service, U.S. Department of the Interior.

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